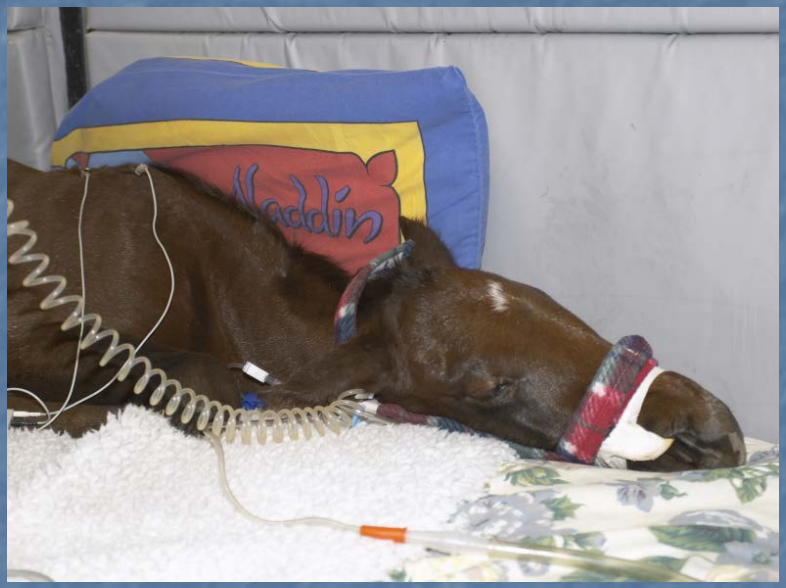
Quantitative Assessment of Metabolic Acid Base Abnormalities



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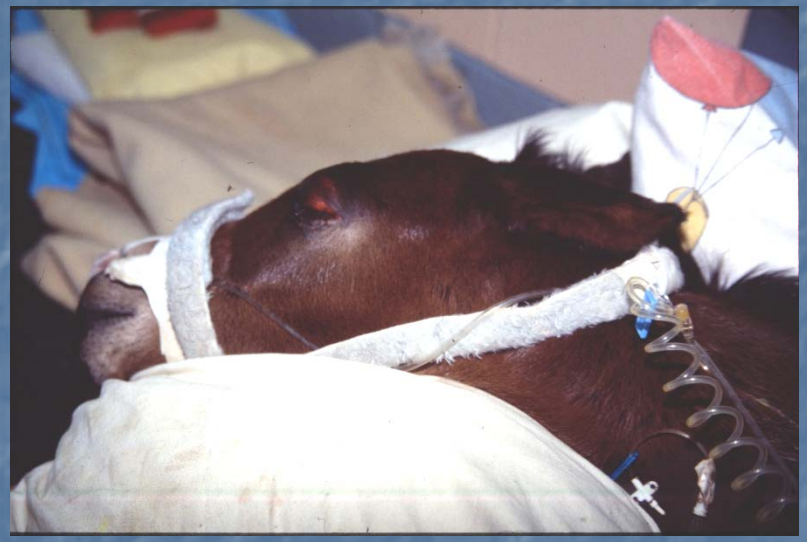
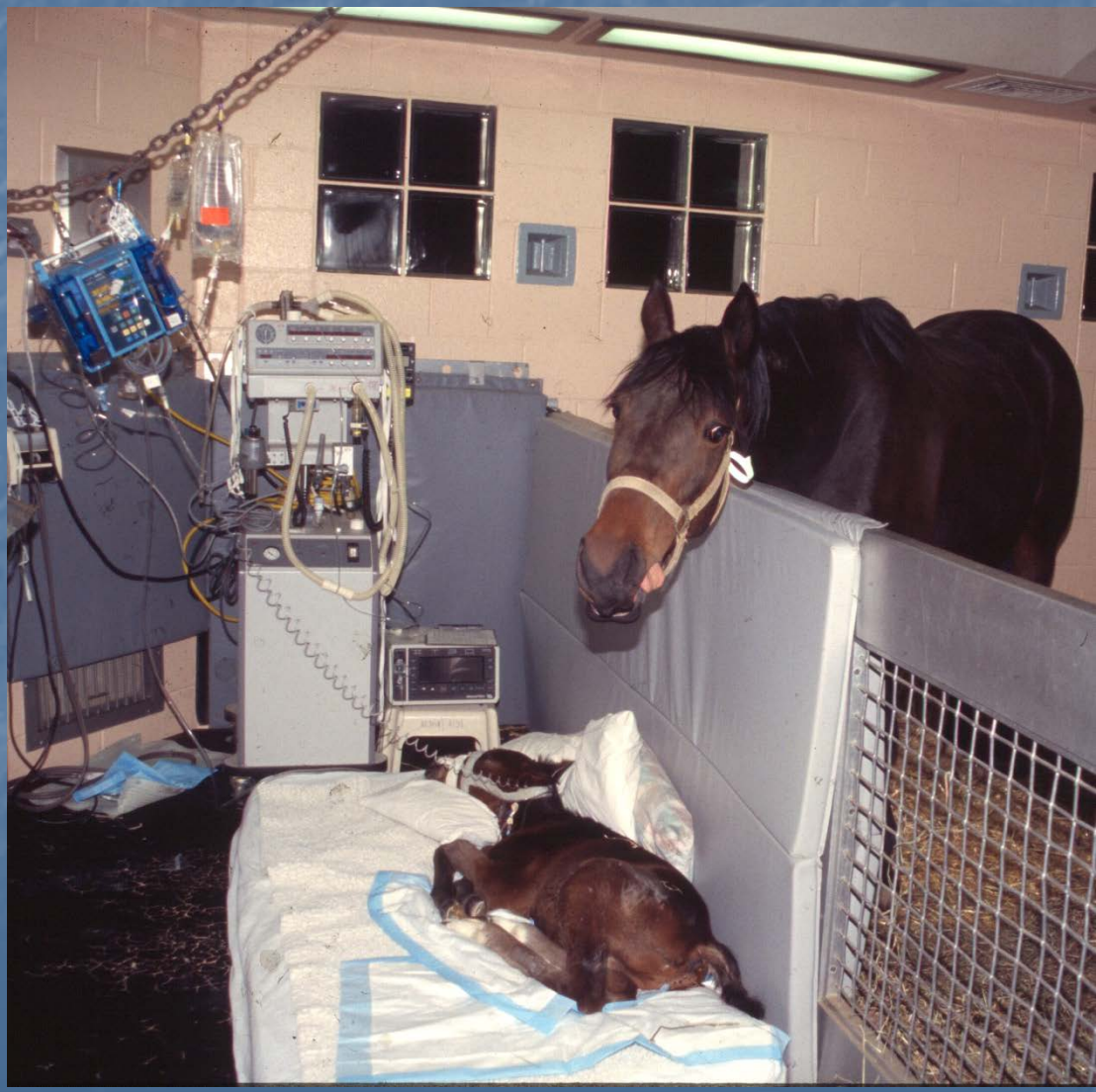
Acid–Base Disorders

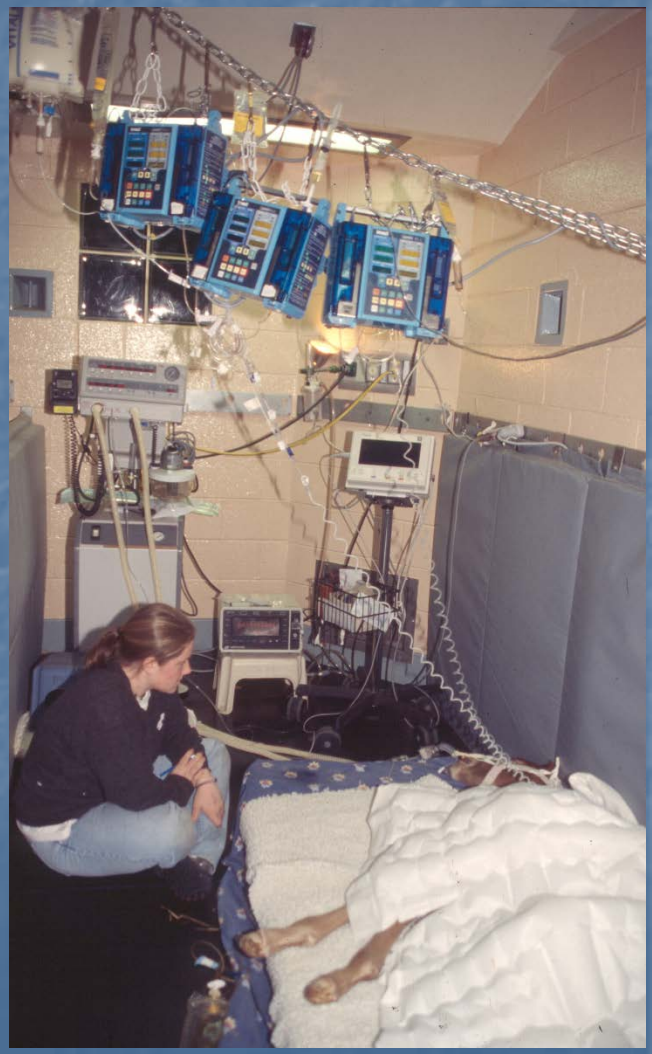




Acid-Base Abnormalities

Alterations in acid-base balance

Less important than the pathologic abnormalities causing them



Acid-Base Abnormalities

- Fatal disorders
  - Extreme (eg, pH <7.0 or >7.7)
  - Develops quickly
  - Direct cause of organ dysfunction
- Harm because of the patient's response
  - Respiratory muscle fatigue
  - Diversion of blood flow from vital organs
  - Acidemia - increased adrenergic tone
  - Increase myocardial oxygen demand

Acid Regulation

- H^+
  - Regulated within a nanomolar
  - Range
    - 16 - 160 nmol/L
    - Normal physiologic value - 40 nmol/L
- H^+ is highly reactive ion
  - Interact with
    - Hydrogen bonds
    - Proteins
    - Enzymes
  - Alter protein structure and function
- Management major importance in clinical medicine

Acid Production

- Primarily CO_2
  - 150 to 250 mEq/kg/d of carbonic acid
  - Hemoglobin is major buffer
    - "Haldane" effect - H^+ bond, HCO_3 to plasma (Cl shift) – 65%
    - CO_2 bound to protein – 27%
    - Pco_2 – 8%
- Strong organic acids
  - 30 to 40 mEq/kg/d
  - Variety of acids
    - Lactic acid
    - Tricarboxylic acids
    - Keto acids
  - Produced/ metabolized to CO_2

Acid Production

- Inorganic acids
  - H_2SO_4
  - H_3PO_4
- Urinary excretion acid
  - 1 to 2 mEq/kg/d anions

History Acid-Base Analysis

- Henderson 1909

$$H^+ \propto \frac{HCO_3^-}{H_2CO_3}$$

- Hasselbalch 1916

$$pH = 6.1 + \log\left[\frac{HCO_3^-}{P_{co_2} \times 0.03}\right]$$

- 1948 – Buffer Base
- 1957, 1958 – Standard Bicarbonate; Base Excess
- 1977 – Anion Gap
- 1981 – Stewart - Physical Chemistry

Which Approach is Right?

- Henderson–Hasselbalch approach
- Standard base excess approach
- Quantitative or Stewart approach

All are correct

Offer different perspectives

Complementary, not substitutive

Stewart Approach

- Principles of physical chemistry
  - Electrical neutrality
  - Dissociation equilibriums
  - Conservation of mass
- Independent variables
  - SID
  - Weak acids (A_{TOT}) – buffer base
  - P_{CO2}

Strong Ions

- Inorganic
  - Na^{+}, Cl^{-}, K^{+}, $SO4^{--}$, Ca^{++}, and Mg^{++}
- Organic
  - Lactic acids
  - Tricarboxylic acids
  - Keto acids
- Strong organic anion
  - “Footprint” or “ghost” of the strong acid

Cations/Anions

Cations

Anions

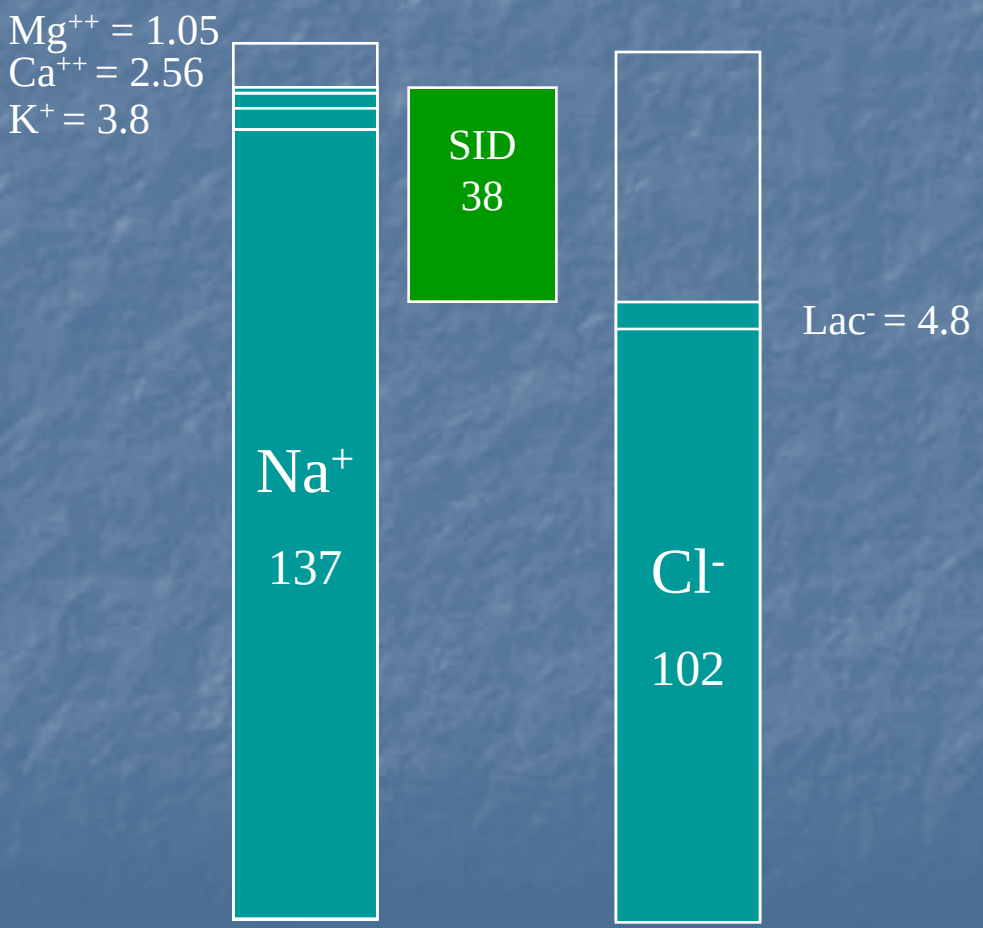
Strong Ions

Cations

Anions

Strong Ions

FIRS, Sepsis		mEq/l
pH	7.46	
Pco_2	39.8	
SID	38	
Na	137 mmol/l	137
K	3.8 mmol/l	3.8
Cl	102 mmol/l	102
Ca^{++}	5.11 mg/dl	2.56
Mg^{++}	1.28 mg/dl	1.05
Lac	4.8 mmol/l	4.8
PO_4	4.14 mg/dl	2.4
Alb	4.9 g/dl	11
Glob	0.76 g/dl	1.1
HCO_3	28.6 mmol/l	28.6
SBE	4.7	



SID

- Approximately 40±2
- Strong ion balance
  - SID > 40 - alkalizing
  - SID < 40 - acidifying
- Quantitate
- Hyper/hypochloremia - relative
  - Decrease Cl < decrease Na – acidosis
  - Decrease Cl > decrease Na – alkalosis

Buffer Base

- Weak Acid Buffer
- Volatile Weak Acid
  - $H_2CO_3 \Leftrightarrow H^+ + HCO_3^-$
- Nonvolatile Weak Acids, A_{TOT}
  - Hemoglobin
  - Albumin (& Globulin)
  - Inorganic phosphate
- Weak acids
  - pK_a act as buffers

Cations/Anions
Weak Ion Acid Buffer

Cations

PO_4^- Hb^-
Alb^- $Glob^-$

Anions

Calculating mEq/l

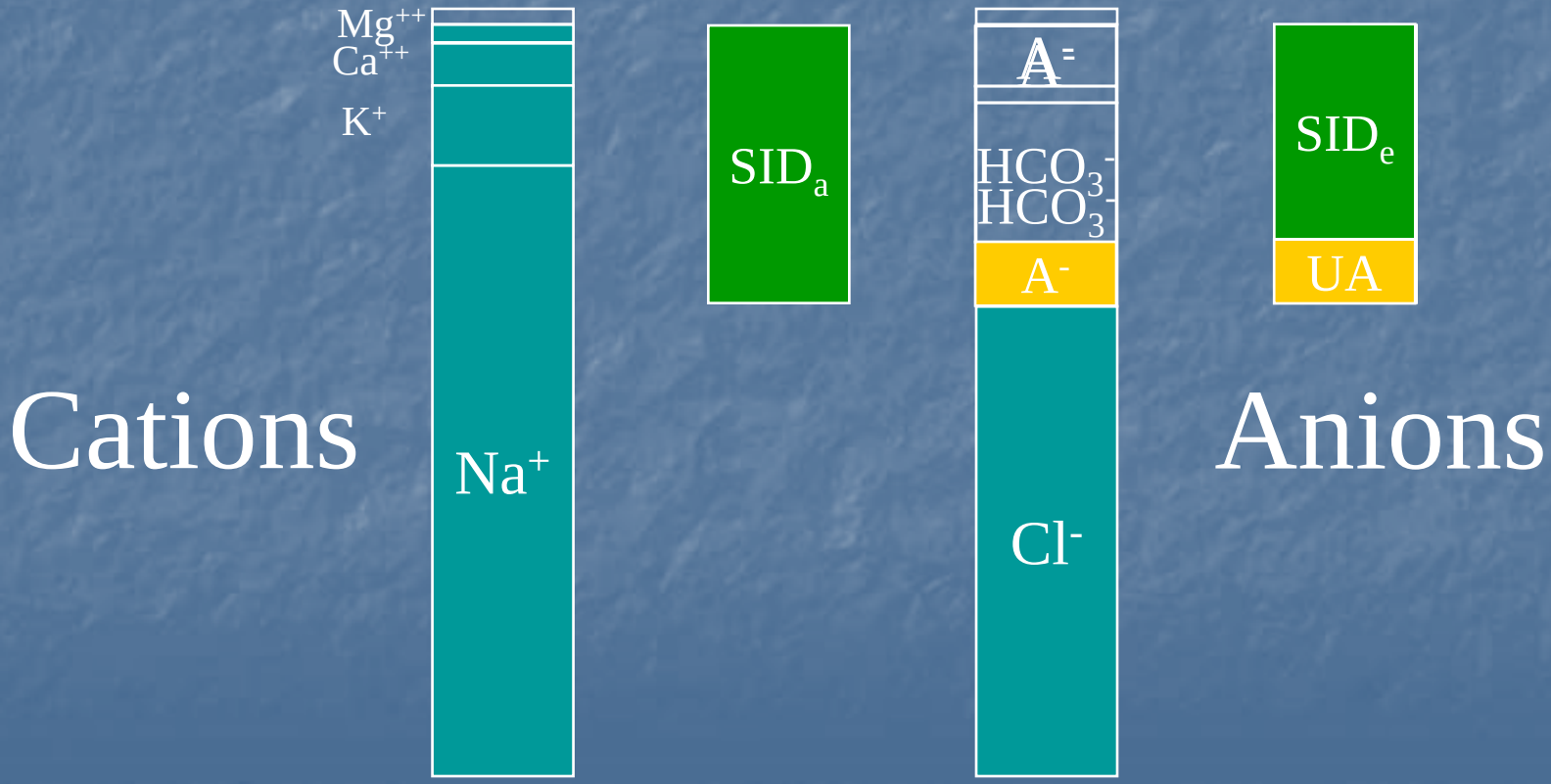
- Alb^- = (Alb x 10) x ((0.123 x pH) – 0.631)
  - Alb^- = 2.8 x Alb
  - Horse: Alb^- = 2.25 x Alb [g/dl]
  - Horse: $Glob^-$ = 1.40 x glob [g/dl]
- PO_4^- = (PO_4 x 0.323) x ((0.309 x pH) – 0.469)
  - PO_4^- = 0.58 x PO_4
  - Horse: $PO4^-$ = 0.59 x PO_4 [mg/dl]

SIG

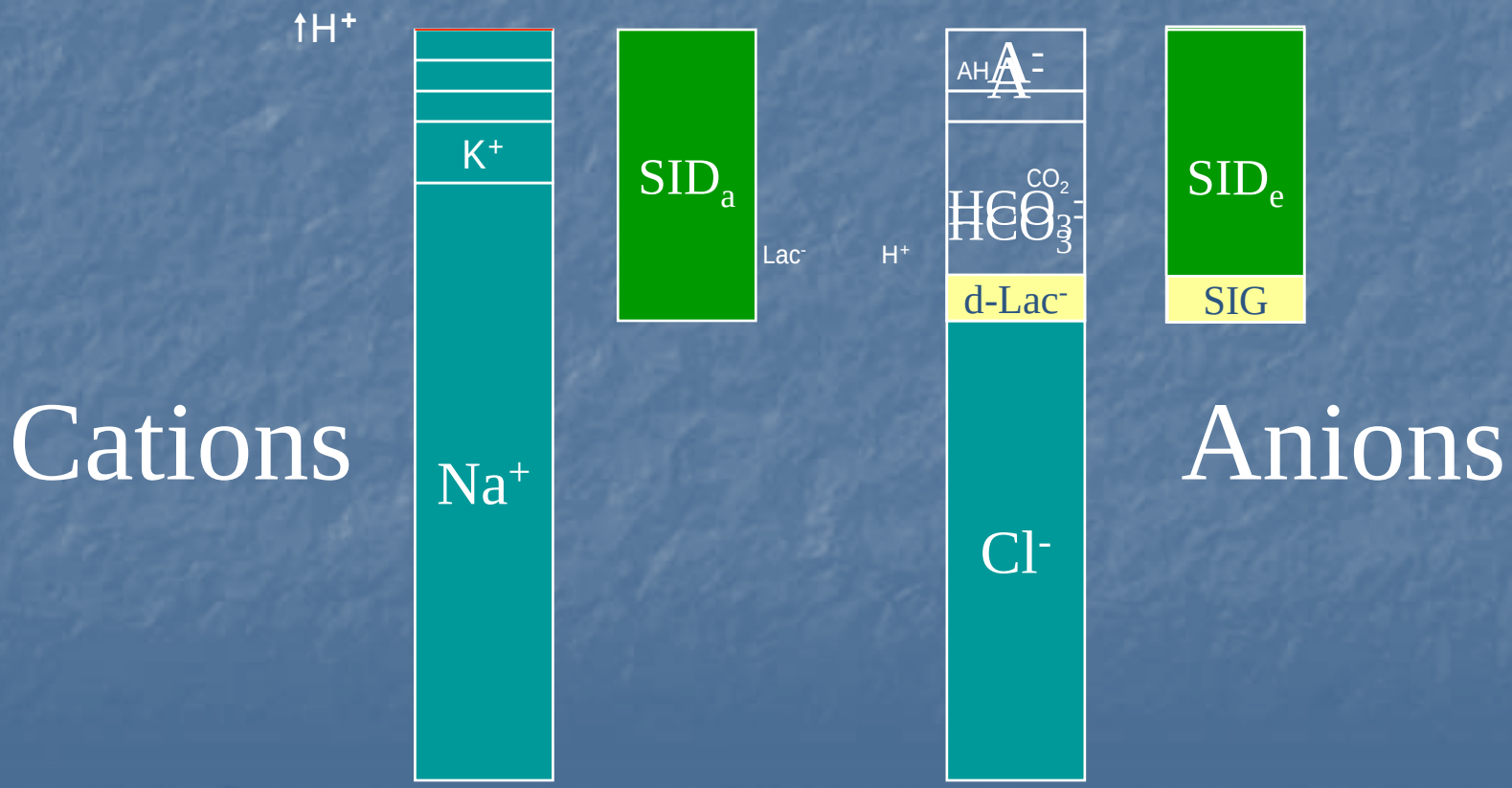
$SID_a = (Na + K + Ca + Mg) - (Cl + Lac)$

$SID_e = Alb^- + PO_4^- + HCO_3^-$

$SIG = SID_a - SID_e = UA - UC = 0$



SIG
d-Lactic Acidosis



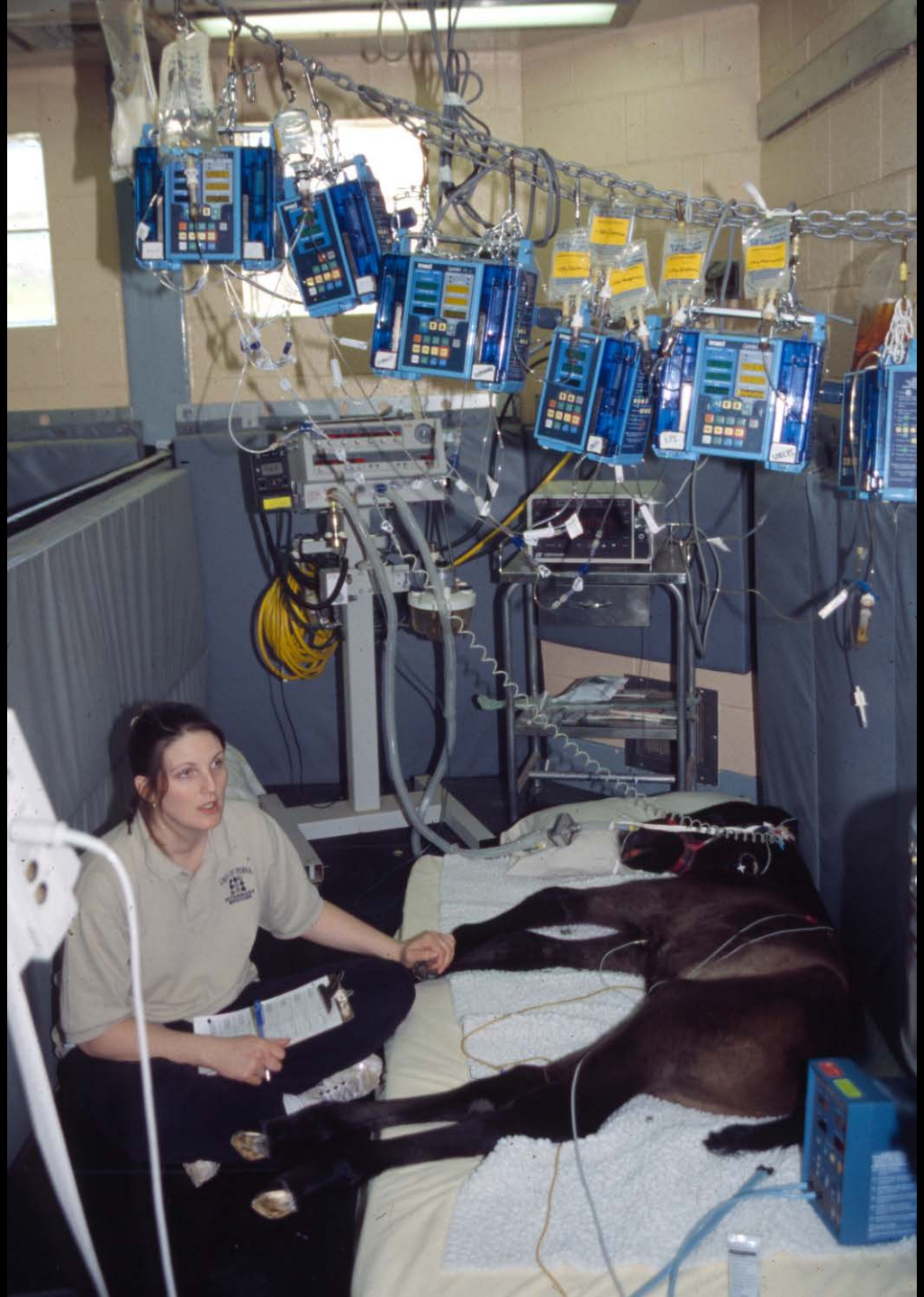
Clinical SIG Calculator

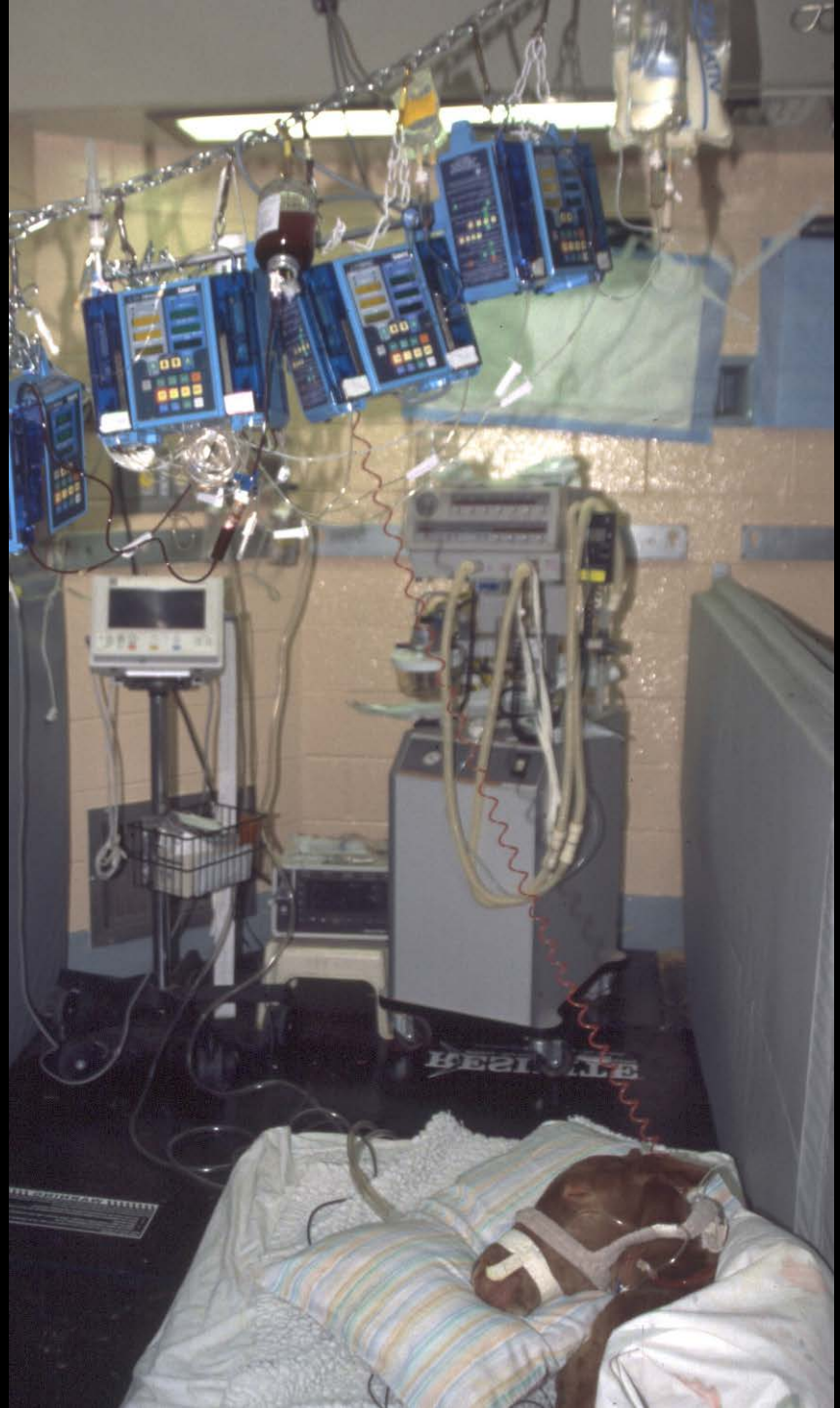
You don’t need an
arterial blood gas to calculate SIG

nicuvet.com

SIG

- SIG = SIDa – SIDe
- SIG > 0 – unmeasured anions
  - Sepsis
  - Liver disease
  - If lactate is not part of SIDa, d-Lac
    - Most common cause of SIG > 0
    - Lactate mmol/l = SIG
- SIG < 0 – increased unidentified cations
- Can have mixed picture but UC very rare
- SIG does not change with
  - pH, Pco_2 changes
  - Changes in albumin, phosphate





Differential Diagnosis Metabolic Acid-Base Disturbances

- Free water
  - Reflected in [Na]
- Chloride – inorganic SID
- Organic anions
- Organic cations
- Albumin level
- Phosphate level

Changes SIDa

- SID acidosis
  - Renal tubular acidosis
  - GIt – Diarrhea
  - Compensation for respiratory alkalosis
  - Iatrogenic – saline (hypertonic less)
- SID alkalosis
  - GIt
  - Diuretics/diuresis
  - Compensation for respiratory acidosis
  - Pathologic renal loses
  - Iatrogenic – sodium loading, $NaHCO_3$

Albumin/Phosphate Concentrations

- A_{TOT}, Buffer Base, weak acids
- Metabolic acidosis
  - Hyperphosphatemia
    - Renal failure, catabolism
  - Hyperalbuminemia
    - Hemoconcentration
    - Plasma/albumin therapy
- Metabolic alkalosis
  - Hypoalbuminemia
- Neonates
  - Hypoalbuminemia
  - Hyperphosphatemia

Unidentified Anions
Unidentified Cations

- Unidentified anions
  - L-lactate
  - D-lactate
  - Endogenous unidentified anions
    - Ketoacids
    - VFA
    - Sulfates
  - Exogenous organic unidentified anions
    - Drugs such as Salicylates
    - Acetate, citrate and gluconate
      - With liver dysfunction
      - Renal dysfunction - gluconate

Unidentified Anions
Unidentified Cations

- Unidentified cations
  - Endogenous organic cations
    - Amines
  - Exogenous organic cations
    - Toxins
    - Drugs
- Detect unidentified anions/cations
  - Numbers don't "add up"
  - "Gap"
    - SIG
  - Occurrence of unidentified cations
    - Can mask the presence of unidentified anions

Unidentified Anions Sepsis

- Lactate, other organic anions (UA)
  - Abnormal intermediary metabolism
- Inflammatory mediators
  - Acute phase proteins
  - Other inflammatory mediators
    - Cytokines
    - Chemokines
    - Other mediators
- Prognosis – UA, SIG
  - Association with outcome
  - Can develop rapidly and resolve rapidly
  - Imply underlying pathophysiologic forces

Acid Base Disorders

- Prognostic value
  - Underlying cause more important than degree
  - Not all acidosis equal
    - Dilution
    - Poisoning
    - Hyperchloremia
    - Saline infusions
    - Dysoxia - lactate production
    - Sepsis - lactate production
    - SIG acidosis